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APPLICATION OF LANDSAT IMAGES IN THE MINAS
GERAIS TECTONIC DIVISION

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16. Abstract This paper presents the results obtained from the interpretation of LANDSAT data for regional geological investigation. Radar imagery, aerial photographs and aeromagnetic maps were also used. Automatic interpretation, using LANDSAT OCT's was carried out the 1-100 equipment. As a primary result a tectonic map was obtained, at a 1:1,000,000 scale, of an area of about 143,000 square kilometers, in the central portion of Minas Gerais and Eastern Goias States, known as regions potentially rich in mineral resources.			
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FOREWORD

Much has been said about the meridional portion of the Sao Francisco Craton and its adjoining areas. The growth of geologic knowledge provided little flexibility to geotectonic outlines previously proposed - the existence of a craton flanked by a belt of marginal folds validates this theory. The present report, which resulted from the interpretation of LANDSAT MSS images and other sensor readings, together with extensive bibliographic analysis and field work, gives scholars the perspective that, with the synoptic vision of LANDSAT images and the large amount of recent geological data from better analysis of the proposed outlines, and better clarification of them, lessens the speculative character of the study areas.

Application of Landsat Images in the
Minal Gerais Tectonic Division

Roberto Pereira da Cunha

CHAPTER I

Introduction

With the development of remote sensors and adequate platforms, the researcher has, increasingly, a better observation point. /1*

The LANDSAT satellite at an altitude of 920 km provides in a single image the synoptic vision of approximately 34,000 km² of the Earth's surface, with sensors operating in a band of 500nm to 1,100nm, comprising four spectral bands corresponding to four images (channel 4:500-600nm, channel 5:600-700nm, channel 6:700-800 nm and channel 7:800-1,100nm).

Therefore, for the study of the 143,000 km² area in this report, encompassed between the 16th and 18th S parallels and 42nd and 48th W meridians, only ten LANDSAT images are needed to cover all regions studied, including adjacent areas.

The authors, making use of LANDSAT images supplemented by radar imagery, aerial photography, aero-magnetic maps, and aided by the Multispectral Analyzer, IMAGE -100, performed geological charting of the Northern region of Minas-Gerais, consisting of the Sao Francisco Basin, Espinhaco Mountain Range and the Southeast portion of the State of Goias.

* Numbers in the margin indicate pagination in the foreign text.

The region under study, occupying the central portion for the most part, includes rocks of the Bambui Group known to have great potential in non-ferrous minerals (Pb, Zn, phosphate, etc.). Various authors studied this region.

In the Western part of the region, rocks of the Araxa and Canastra Group are located. In the Eastern portion, there are rocks of the Espinhaco and Macaúbas Groups, also containing various minerals (Au, Fe, Diamond, Cr, Ni, Pt, etc.).

Until recently, geology maps covering the investigated region were unknown in sufficient scale for regional integration. Currently, studies have been made, among others the DNPM and NUCLEBRAS studies (Ex: Goiania II Project, Meridional Espinhaco Project) and the "Mapa Geológico de Minas Gerais" (Minas Gerais Geologic Map), and yet to be published, "Folha Geológica Belo Horizonte" (Belo Horizonte Geologic Folio), by INPE and "Carta Geológica" (Geologic Map) on a 1:1,000,000 scale, by DNPM in Belo Horizonte.

Geological chartings in later years, for the most part, are the result of data collected from previous works, and they usually simply change the dimension of geological investigations, not greatly changing their content, with no new data being added to verify or correct them. Speculation in previous works still remains. Thus, naturally, investigations only change in graphic scale, and, concepts are elaborated upon them.

Lack of geologic knowledge of many areas of the country cannot be credited to a lack of data, for, in many cases the information exists, and even in abundance. The interpretation and integration of these data and the utilization of sources available are what is needed.

Studies in Brazil can now make use of such advanced tech-

niques as used in more advanced countries. Sensible use of new technology along with previous knowledge can bring about many benefits in several areas of the geosciences.

The application of new methods for geological studies, utilizing remote sensor data collected on different levels, i.e., from satellites, airplanes, etc., constitutes a valuable tool for innumerable geologic surveys.

Basically, the implementation of these techniques in geological charting allows the acquisition of a vast array of data, leading not only to the charting of the whole area studied, but also to the choice of more promising areas which then would be subject to a detailed survey.

In this aspect, various sensor devices used, mainly LANDSAT and radar systems, contribute greatly to the recognition level, which leads to broader studies of different subjects (tectonics, metalogenetics, etc.). Consequently, the techniques used here allow us to obtain basic data so as to be able to integrate pre-existing geologic data and to evaluate, update or develop the knowledge of a determined area from (isolated) investigations conducted.

CHAPTER II

Discussion of Results

The study area was divided into two parts: the Eastern Sector, represented by the Sao Francisco Craton and the Espinhaco Mountain Range; and the Western Sector, covering the "Brasilia Fold Belt".

2.1. Eastern Sector

In this sector we describe the Sai Francisco Craton

and Espinhaco metamorphites.

Over two decades ago, many studies of this portion of the Brazilian Shield were developed, thus producing a better understanding of the Sao Francisco Platform.

Guimaraes (1951) recognizes the Sao Francisco Craton ("Arqui Brazil") as a structural element of the Brazilian Shield and introduces the concept of continental nuclei flanked by newer geosynclines, in which the Sao Francisco Basin would be an archaic nucleus flanked by Proterozoic formations of the Espinhaco Mountains.

Barbosa (1954) describes a complete geotectonic cycle, beginning an eogeosyncline evolution (Pre-Minas) with a miogeosyncline evolution (Minas) and culminating post-tectonic sequences (Lavras and Bambui). /3

Pflug (1965) designates this cratonic area the "Sao Francisco Massif" east of the Espinhaco Mountain Range, attributing to it the responsibility for the Minas geosyncline sediments. The author shows that the Meridian Espinhaco Mountain Range, during the sedimentation period of the Minas Series, was the marginal zone of a great orthogeosyncline (according to Stille, 1936, Kay, 1951, Dietz 1963) and describes the facies interdigitation (miogeosyncline and eogeosyncline).

Suszczyński (1968) applied the concept of the geotectonic cycle (Harpur, 1960) in studying the Eastern portion of the Eastern Brazilian Shield east of the "Brasilia" orogenic belt, including not only the Sao Francisco River Basin but the Espinhaco Mountain Range orogenic belt as well.

Pflug et al (1969) reconsider the Sao Francisco Craton as

a more restricted area occupied presently by the Basin of the Sao Francisco headwaters, bordering the Espinhaco Mountain Range on the east, from the Ferriferous Quadrilateral to the Boqueirao Mountain Range (Bahia). They arrive at the conclusion that the Espinhaco Mountain Range and surrounding areas were structures for orogenetic cycles: the Pre-Minas cycle, which was verified in a region already partially cratonized and the Minas/Bambui cycle, which began with the formation of an orthogeosyncline around older continental nuclei.

This Craton of Transamazonian age (1800-2200 million years) borders the Western portion of the Brazilia marginal fold belt as seen below.

The following represents a synthesis of considerations drawn by Pflug (1965-1969), Pflug et al (1969) and Pflug et al (1973), who contributed to the study of the tectonic evolution of the area corresponding to the Espinhaco Mountain Range.

Pflug (1965) applied the geosyncline concept and facies distribution to the mining regions east of the Sao Francisco Basin, presenting in his report the outline of the evolution of the "Minas Series" sedimentation of the post-orogenic phase with disposition of sediments of the "Lavra Series" and the beginning of the "Bambui Series" sedimentation in the Sao Francisco Basin, which began to subside at the onset of the Espinhaco orogenesis.

After the 1965 and 1967 reports, Pflug et al (1969) considered that the evolution of this mountain chain resulted from two cycles - Pre Minas and Minas/Bambui, and arrived at the following conclusions:

1. The existence of a stabilized region before the displacement of the Minas Group (Sao Francisco Craton);

2. On the Craton edge a great orthogeosyncline was formed where the Minas Group was deposited, with rough clastic facies (Diamantina facies) indicative of riverside regions, less stabilized and occupied by the Minas miogeosyncline;

3. With the central zone folds of the geosyncline and terrain inversion, the displacement of the Bambui Group was started, in platform facies, in the basin which had to be molded (showing that fine carbonic clastic facies of Bambui correspond to the contribution of cratonized areas);

4. Synorogenic sediments in riverside regions also began to be furnished by the geosyncline central zones. These sediments, corresponding to Macaúbas Suite, interlace with the typical Bambui, as they head towards the Craton (thus they are restricted only to the Minas orthogeosyncline riverside zones);

5. There are inconsistencies between Minas and Bambui which are synorogenic, and the degree of metamorphism, the deformities and folds reached the two entities in the same way, showing a continuous process in which the inconsistency marks terrain inversion which accompanied the geosyncline orogenesis.

6. In the two maps presented (facies distribution and tectonic style) it is shown that the cratonic nuclei control the distribution of zone facies and that the behavior of tectonic and metamorphic structures present fold axes contouring the cratonic nuclei. The convergences are directed toward the Craton, even though the tectonic style may vary considerably locally, due to the degree of stability of the adjacent Pre-Minas crust and to the thickness of quartzites;

7. Due to the dimensional similarities, eogeosyncline facies distribution, existence of ultrabasic and basic rocks, fold axis continuity, convergences, metamorphic zone distribution, and

cratonic region influence, they compare the Minas geosyncline with others belonging to the precambrian-Otavi/Damara, South Africa, Karelium/Svionum, Baltic Shield, Labrador, etc.

Pflug (1973) correlated the quartzite and phyllite sequences of the main Espinhaco Mountain with the Ferriferous Quadrilateral sequences, as well as the schists and gneisses just East of the Mountain Range. Within this concept he established three great divisions for the Espinhaco regions separated by angular variance: Post-Minas, Minas and Pre-Minas.

Pflug stresses that the "Minas Super Group" magmatism is typical of the geosyncline sequence (Stille initial magmatism), with basic and acid rocks concentrated on the "Itabira facies" (geosyncline external edge), although other facies may contain syno-sedimentary magmatic rocks.

The "Minas Super-Group" is affected by strong tectonism which compresses the geosyncline basin in the direction of older area (Sao Francisco Craton), resulting in folds of several orders of magnitude and enjambment. Clastic sediments are formed in the geosyncline belt in smaller basins. The predominant pelitic and Chemical sedimentation appears with the presence of an epicontinental sea, resulting from the help of the ancient Craton.

To this new paleographic distribution of the so-called "Sao Francisco Super Group" correspond later sediments of the Minas chain lift up.

The effects produced by the lift-up of the eastern and western edges, the Espinhaco and Araxa-Canastra geosyncline, respectively, are evident not only in the sedimentation (basal portion) but also mainly in the tectonic style of the Bambui and Macaubas Groups. The tectonic transport of the edges, with convergences to the Sao Francisco Craton, originated the extensive thrust or inverse faults, which threw rocks from these belts onto the rocks

of the Sao Francisco Super-Group. Due to tangential forces, pelitic-carbonic sequences of the Bambui basin exhibit a complex fold style close to the edges, which diminishes towards the center of the basin.

In geologic map analysis one can note the structural parallelism of calcareous, phyllitic and slate rocks of the Macaúbas and Bambui Groups with the curving of the Western edge of the Espinhaço (geosyncline domain).

Notable ruptural tectonic is shown by the Espinhaço, Macaúbas and Bambui Groups. This ruptural system, with approximate north-south and east-west directions of the precambrian age, was successively reactivated, reaching the Cretaceous age.

As can be seen, Reinhard Pflug is one of the researchers who studied the Espinhaço Mountain Range in more detail than others. Almeida, (1976b) proposes a new fold belt for this area, formed about 1,000 million years after consolidation of the Espinhaço belt. This proposed belt, termed the Aracuaí Belt, was developed under miogeosyncline conditions in the region corresponding to the displacement of the Macaúbas Group. The sequence forming this belt is made of detritus deposits, reaching 2000 m thickness and showing growing polarity and metamorphism from the Craton edge, reaching the amphibolite facies with cyanite and presenting granitic intrusions (for example, Coronel Murta, Aracuaí-Minas Gerais). Volcanic rocks are also found in the upper Macaúbas.

2.2. Western Sector

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2.2.1. "Brasília Fold Belt"

The "Brasília Fold Belt" located on the Western edge of the Sao Francisco Craton is defined by Almeida (1967) as the "Brasília Fold Belt". It includes the "Brasilides" structures of J. Keidel (1921) and the "Araxaides" structures of M. Ebert (1956), respectively,

of miogeosyncline and eogeosyncline character.

The miogeosyncline belt is composed of tectonized meta-sediments in the Baikalian cycle, whose lower terrigenous sequence holds phyllites, mica-schists, paragneisses, quartzites and calcareous rocks of the Canastra Group and, pro parte, of the Araxa Group. The pre-inversion carbonate formations of calcareous rocks of the Sete Lagoas Suite are next, covered by an upper terrigenous sequence represented by the Tres Marias arkosics. The corresponding eogeosyncline would be composed of biotite, schists, marbles, paragneisses, quartzites, amphibolites, meta-basites and other rocks of the Araxa Group.

This fold belt, still according to Almeida (op. cit.), together with the Paraguai-Araguaia Belt, would form a great bimarginal bimarginate geosyncline or a geosyncline of centrifugal polarity, having a common internal area of divergent symmetry from pre-Baikalian rocks, constituting a "Zwischengebirge" or newer area "Macico Mediano Goiano" (Goiás Median Massif).

Almeida (1968), in a later report, redefines this geosyncline system: "We originally thought that the Araxa Group represented the coeval eogeosyncline of the Brasília miogeosyncline but field observations, geochronologic studies and the geographic distribution of the Canastra Group showed that it is younger than the Araxa Group.

Therefore, the Araxa Group which rests in angular variance over the basal complex, constitutes meta-sediments of eogeosyncline character, penetrated by syenites and a great number of basic-ultra-basic intrusions, the miogeosyncline being composed of the Canastra and Bambuí Groups, with Paracatu and Cristalina formations constituting the lower structural stage. The Paranoá suite, in angular variance over the Canastra sequence term, initiates the following structural stage (which was adopted by the Carta Tectônica do Brasil (Tectonic Map of Brazil) (1972) as a medium and superior stage still

composed of the Sete Lagoas suite and rio Paraopeba, the latter a member of the Tres Marias and of molassoid character.

Almeida and Hasui (1970) explain the extemporaneity between the eogeosyncline and miogeosyncline sequences with polycyclic interpretations, considering the Araxa Group as pertaining to the Uruacuan Cycle (1300-900 million years) and the Canastra and Bambuí Groups as belonging to the Brazilian Cycle (900-550 million years), ancient and recent, respectively. This is supported by the "Carta Tectonica do Brasil" (Tectonic Map of Brazil) (op.cit.): "The Brazilian Fold systems developed in crust regions affected by long instability, where previous fold systems did not have definitive consolidation conditions.

Costa and Angeiras (1966) analyzing geosyncline polarity evidence (orogenic and sedimentary) in Central Brazil's fold belt recognize seven isopic zones (cratonic zone, pericratonic zone, miogeosyncline zone, subgeoanticline zone, miogeoanticline zone and eogeosyncline zone, and the ancient pre-Baikalian base) as portions of an ample geosyncline system, polycyclically developed during a long Baikalian cycle of 1000 million years (\pm 1500-500 million years).

The eogeosyncline (Minas-Uruacuan cycle) and the miogeosyncline (Brazilian cycle, according to the authors cited above), constituted a "quasi-orthogeosyncline", evolving parallelly in space and progressively in time, comprising the Baikalian cycle, the Minas-Uruacuan and Brazilian cycles, constituting mere diastrophic phases within a geosyncline process.

Referring to Russian authors (Shatsky, 1957 and Belikina, 1968), they stress that a cycle must be established in the transformation phases of an orogenetic area, in "platform making". /6 These authors: Costa and Angeiras (op.cit.), propose that the Brazilian and Uruacuan cycles of this fold belt be embodied in a Brazilian Cycle, increased from "800-550 million years" to \pm 1500-500 million years.

The "flysh" contribution to the miogeosyncline is given by the orogenesis of the eogeosyncline (Auboin, page 111). Therefore, naturally the miogeosyncline formations are newer than the eogeosyncline formations of an identical geosyncline system.

Costa and Angeiras (op,cit.) take it that the eogeosynclinal Araxa Group sequences would be progressively correlated with members of the Canastra Group and more westerly sequences of the Bambui Group with miogeosyncline facies.

The miogeosyncline sequence (Canastra and Bambui Group) begins with the Canastra Group, in incompatible contact with the Araxa Group rocks without magmatism. The eogeosyncline sequence, on the contrary, shows an intense magmatism. Both sequences show sedimentary and orogenic polarity characteristics. Nevertheless, they present a distinctly orogenetic break, in space and/or time.

Existing data are not conclusive for the Uruacu belt. Dating indicates that the Brazilian cycle rejuvenated the Uruacuan rocks, which possess significant results of 1,000 million years, corresponding to the minimum age of the metamorphism. According to Almeida (1976), the values of 1,300 million years and 1,000 million years may correspond to the regeneration limits and tecto-orogenetic evolution of the Uruacuan cycle.

Known characteristics of these rock sequences such as structures, magmatism, metamorphism, etc., as well as geochronological dating, due to the "imprint" of the Brazilian cycle in the rocks of this western portion of Minas Gerais, have not yet appeared to define the tectonic evolution of the region.

Amaral et al (1976) stress the possibility of a gradual passage of Araxa metamorphites to Bambui Group rocks. Almeida (op,cit.) also accentuates this aspect: "The Araxa Group seems to pass gradually to the metamorphites of the Brasilia belt. As a result, the border between the two units is not easily marked", despite

considering it possible that the Eastern borders of the Uruacu belt were caused by a thrust fault, throwing the Araxa Group over parts of the Brasilia Belt.

The evolution of this belt, which we term the Brasilia Belt, resulted from one or more orogenic cycles, and seems to different authors a problem of the breakup, which is clarified by some and restrictive to others: the ending and beginning of the Uruacuan and Brazilian cycles or, as a whole, the evolution within a single cycle.

From the metallogenetic point of view there are two well defined areas: The Uruacu belt, which has a richer metallogenesis with periodotitic belt, presenting mineralizations of Cr, Ni and asbestos; and the Brasilia belt, with absent magmatism, with sedimentary deposits of phosphate and syngenetic deposits of Pb and Zn remobilized in fault zones. These are metallogenetic areas formed in different times and/or spaces and mineralizations formed within certain phases of this fold belt. The question then remains open: are these phases merely diastrophic within a long cycle (Baikalian) or do they result from two consequent orogenic cycles (Uruacuan and Brazilian).

2.2.2. Borders of the Fold Belt

All sequences presented below, with the exception of the Molassoid sequence, occur west of the Sao Francisco River, as observed in the attached outline. They being north, between Brasilandia and Bonfinopolis de Minas and south, at Joao Pinheiro, where one can observe parallel and subparallel structures with a predominant NNW direction, which are well observed in the LANDSAT images and more diffuse than those of the Preto river region.

The Brasilandia region is limited on the east by the great fault which runs from the Sao Domingos Mountain Range (Sao Domingos Fault). The southern border is covered by rocks of the Tres Marias suite and Crestaceous rocks, and corresponds as was suggested by 47

Costa et al (1970) and Almeida (1976b), to the fault shown in the LANDSAT images from Canoeiros (Minas Gerais) until it becomes hidden in the argilo-sandy deposits of the Paracatu river. To the west, the border of this region corresponds to another great fault which runs in the Preto River Mountain Range (Rio Preto Fault). Costa et al (op,cit.) consider the described area as a pericratonic zone, its passage to the cratonic dominion being abrupt as well as transitional.

The intense lineament zone (folds and faults) of the Preto river region (Unaí-Minas Gerais), is situated within the miogeosyncline belt (DNPM-1968, Costa et al, 1970), which runs to the west of Joao Pinheiro - Minas Gerais). This zone is marked by a continuous and narrow standard of folds, typically holomorphic.

To the west the structures become less frequent, more sparse and without a defined standard. It should be stressed that this region appears well hidden, due to erosive cycles and coverings. In the Piloos Mountain the quartzites are all directed towards the northwest, forming high points, together with the Cristalina region (Goiás) and Brasília (Federal District), corresponding to the limits of the miogeosyncline zone of Costa et al (1970).

On the Paracatu-Minas Gerais northwestern end, the structures seem to break off to the east, which made many authors define them as thrust faults and as the limit of the Brasília miogeosyncline belt (DNPM, 1968, Almeida, 1972 and others), and also the limit of the anticline of Costa and Angeiras (op,cit.).

The miogeosyncline border sequence in this report corresponds to a sinuous line, which passes north of Luziania, west of Cristalina and south-southeast of Sant Antonio do Rio Verde (Goiás), corresponding to the contact of the Araxa Group with the Bambuí and Canastra Groups. Certain portions of this border are marked as a thrust fault.

The eogeosyncline sequence, whose borders exceed the charted area, presents razed structures, series of anticline and syncline lineaments, faults and fractures (NW), mainly south of Santo Antonio do Rio Verde, can be identified.

From the above we can conclude that there exists an orogenic and sedimentary convergence in a westerly-easterly direction from all these sequences, marked by the lower level of metamorphites in this region and changes in sedimentary sequences.

2.3. Tectonic Units

In the following, we present the division adopted for the fold belts, using a very flexible interpretation. In this report we refer to the Rast's concept (1969) when referring to fold belts.

2.3.1. Precambrian Sequences Affected by Folds

Included in this division are the metamorphic rocks of the Espinhaco Mountain Range which are affected by a considerable degree of deformity and metamorphism.

1. Complexes

These deal with rock sequences composed of granites, gneisses and schists consolidated in pre-Baikalian cycles and rejuvenated in the following cycles.

2. Espinhaco Metamorphic Sequences

These correspond to the Espinhaco Group lithologies which are affected by folds (N-NE) and thrust faulting. They are distributed in the Espinhaco and Cabral Mountain Range where they possess schist facies metamorphism. The metamorphism is of the Barrovian type, and can even reach the Mesozone. It includes the Espinhaco fold belt ("Carta Tectonica do Brasil" (Tectonic Map of Brazil) 1972, Almeida, 1976b, DNPM, 1968).

3. Metamorphic Sequences and Macaubas Meta-Sediments

These include only the metamorphites of the Macaubas Group

defined for the Espinhaco Mountain Range. This group of rocks, with well pronounced schists, occupies the greater portion of the Espinhaco Mountain Range, with southeast borders in the Capelinha region, in Itamarandiba, and with complexes. The meta-conglomerates of this sequence appear deformed with elongated pebbles. In the Coronel Murta and Aracuai regions (Minas Gerais) some acid intrusions (granites) can be observed. This sequence shows metamorphism of a low degree, increasing to the east. It corresponds to the detritic sequence of the Aracuai belt (Almeida, 1976b), also to the distribution of the miogeosyncline sequence (Pflug, 1973) and to the miogeosyncline sequence (Catunides of DNPM, 1968).

2.3.2. "Brasilia" Fold Belt

2.3.2.1. Eogeisyncline Metamorphic Sequences

These occur in the westernmost sector of the charted area, comprising the Araxa Group metamorphites. It is the sector with the greatest metamorphic level (it reaches the epidotamphibolite level, and has evidence of magmatic intrusions, grandiorites or pegmatites). This metamorphic sequence corresponds to the Minas-Uruacuan cycle of Almeida (1968) and Angeiras et al (1970), representing the Uruacu belt of Almeida (1976b).

2.3.2.2. Meogeosyncline and Meta-Sedimentary Sequences

This group includes the lithologic sequences of the Canastra and Bambui Groups, appearing west of the Sao Francisco River.

1. Terrigenous Sequence

This sequence includes the lithologies of the Canastra Group, which show a predominance of pelitic to psammitic sediments. It shows structures with NNW directions, with metamorphites of green schist, constituting the inferior sequence of the miogeosyncline belt. It corresponds to the distribution of the Goianides belt of DNPM (1968), miogeoanticline zone of Costa and Angeiras (1969).

2. Mixed and Carbonic Sequences

This is composed of the Paranoa formation (terrigenous) and Paraopeba formation (mixed and carbonic) of the Bambui Group. It is varied, including calcareous rocks, dolomites, arkosics, quartzites, phyllites, slate, etc. It is the sequence with the greatest lithologic variety of this fold belt and with the greatest volume of carbonic rocks. It shows displacement characteristics in a neritic environment, which many times makes the stratigraphy of the region difficult. There is also a very great horizontal and vertical variation of lithologic components. Calcareous rocks (dolomites) are intermittent and more predominant in the Unai-Vazante axis area where the lithologic change is more pronounced. It is possible that the Paranoa formation is part of the lower terrigenous portion and also constitutes a separate formation of the Bambui Group. This unit corresponds roughly, to the Formosa Tectonic group of Costa and Angeiras (1971) and to the preinversion "calcareous" of Almeida (1969).

2.3.2.3. Meta-Sediment Sequence Affected by Folds

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Formed primarily by slates, and secondarily by arkosics and rarely calcareous. It presents a less intense fold and a smaller change in lithology than the previous sequence. It is situated between the Unai fault (Rio Preto Fault) and the Sao Domingos Fault. Its passage to the craton zone is not well known. Close to it, the folds are sparser and of little amplitude. It corresponds to the pericratonic zone of Costa and Angeiras (1971).

2.3.2.4. Molassoid Sequence

This sequence is distributed in the central portion of the charted area on the fold zone (fold belt), as well as on the non-fold cover region (craton). It corresponds to the Tres Marias arkosics, which constitute the upper Terrigenous sequence. This sequence is called molassoid because it does not possess typical characteristics of a foredeep molasse, where magmatism is absent, like the entire miogeosyncline belt (Almeida, 1968, Costa and

Angeiras 1971, DNPM 1972).

2.3.3. Platform Coverings (Craton)

These include the Sao Francisco Craton covers, which apparently were not affected by great deformities, but were subject only to a platform-like tectonic.

2.3.3.1. Precambrian Covers

1. Covers with Clastic Predominance

These comprise the Jequitia suite clastics with glacial origin contributors, diamictites, conglomerate arenites, depleted of carbonic sediments and prior to the Bambui Group displacement. These are sequences with intermittent folds (idiomorphic), and they do not present an appreciable deformity level. They can be correlated in time with Macaubas metamorphites, but they are of a different formation.

2. Covers with Clastic and Chemical Predominance

These include the Bambui Group lithologies, deposited on the craton which are formed by fine and carbonic clastic facies. These were deposited soon after the Jequitia suite displacement, or in certain places they can even be interlaced with superior lithologic members of the Jequitia suite. They present horizontal and subhorizontal layers which show chemical proportions and fine clastics, larger than the corresponding lithologies of the folded belt. Structures such as covers are the result, for the most part, of rigid tectonic ("Blockgebirge" of Stille, Auboin, 1965, page 21) with idiomorphic folds.

2.3.2.2. Mesozoic and Cenozoic Covers

These incorporate those arenous, argilo-arenous and detritus deposits formed during the Mesozoic reactivation ("Wealdenian").

These are (Mesozoic) deposits of the Areado and Urucuia

Formations, with magmatism absent (fissural, toleitic) and with small faults and fractures. They denote the behavior of a stable and rigid crust.

The accumulation of this type of deposit started with the decline of activity after the Sao Francisco Basin Triassic. The lowering of displacement of Areado and Urucuia arenites occurred under conditions of slow decline, because conglomerates do not show fast displacement characteristics (thickness, maturity, etc.) and they are distributed in a modest vertical expression and are very extensive sandy displacements.

Cenozoic deposits are sufficiently varied and formed in assorted conditions. Tertiary deposits of the Sao Domingo plateau are the largest ones, reaching one hundred meters; these formed in a restricted basin in the Espinhaco Mountain Range and are composed of arenites with argilous levels.

Chapter III

Conclusions

Units and structures extracted from LANDSAT images allow the elaboration of tectonic outlines in regional scales of great areas from which evolution models of the Earth's crust and its metalogenetic dominion can be established.

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The investigated area shows, through the images, very significant elements for the establishment of tectonic unit borders as, for example, the Sao Francisco Craton. On the other hand, this study allows us to conclude that there is an orogenetic and sedimentary convergence of all sequences of the western sector and in the opposite direction do not possess such definitive elements.

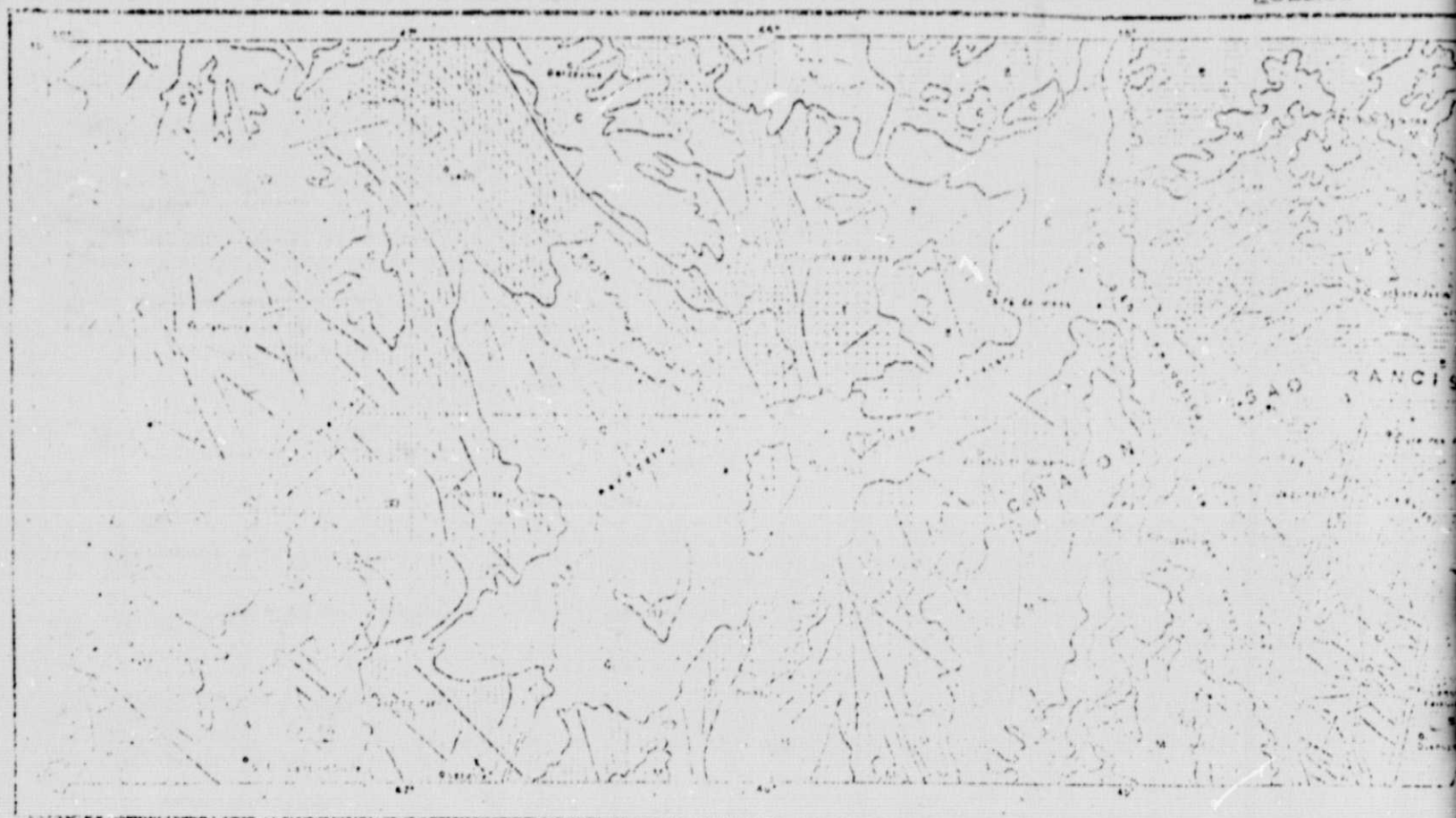
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EOLDOUT FRAME

ESBOÇO TECTÔNICO DO NORTE DE MINAS GERAIS BASEADO EM INIA EOLDOUT FRAME



Este esboço tectônico foi elaborado com base nos dados geológicos disponíveis na literatura e em trabalhos de campo realizados no norte de Minas Gerais.

Elaborado por:
LUIZ CARLOS DE MATTOS
Assessor Técnico de Geologia

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B LOCALIZAÇÃO DA ÁREA



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SD-02	SD-05	SD-06
SD-07	SD-08	SD-09

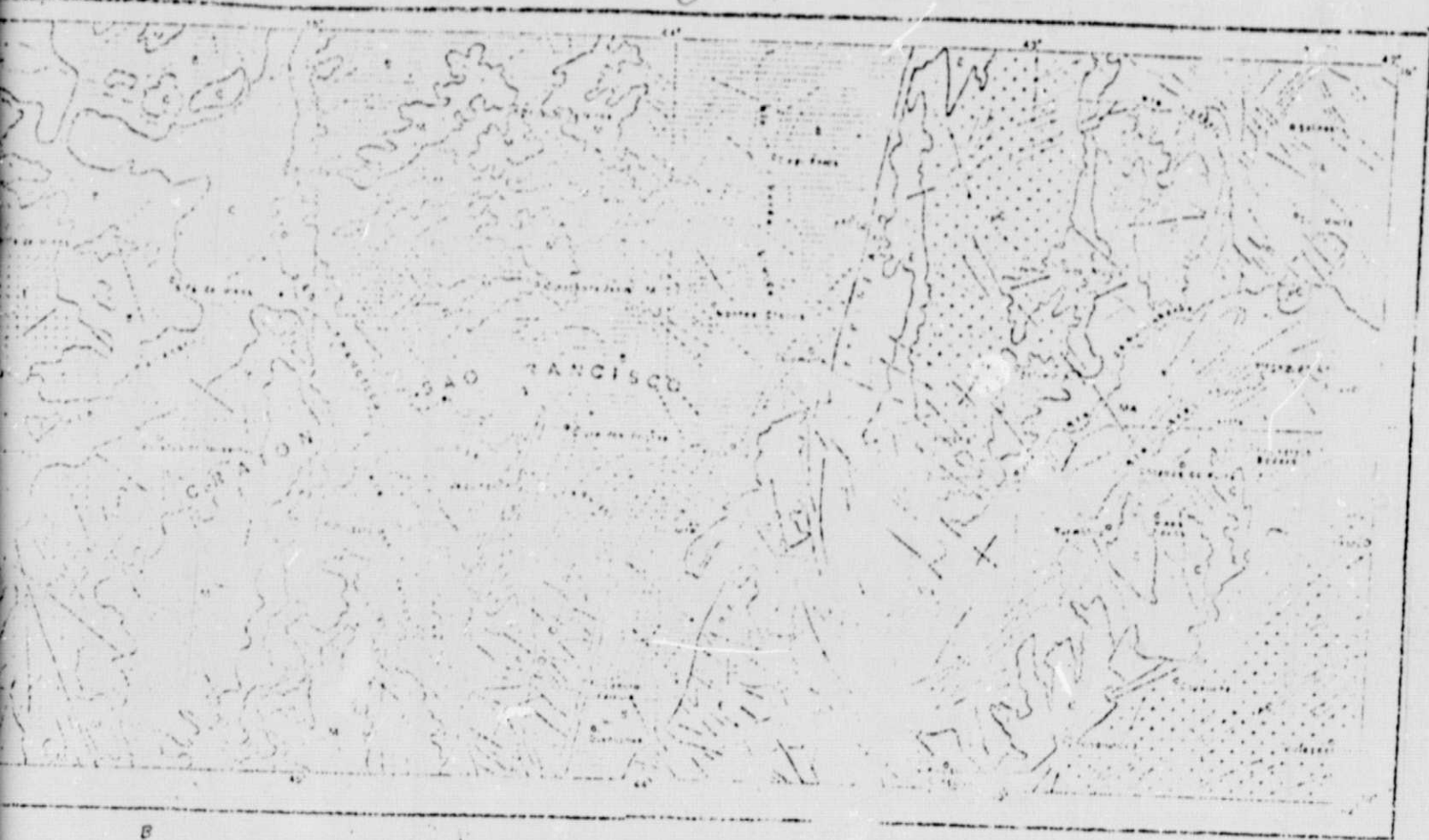
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Fig. 1.

CO DO NORTE DE MINAS GERAIS BASEADO EM IMAGENS LANDSAT
 EOLDOUT FRAML 2



B LOCALIZAÇÃO DA ÁREA



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21-22	21-23	21-24
22-23	22-24	22-25

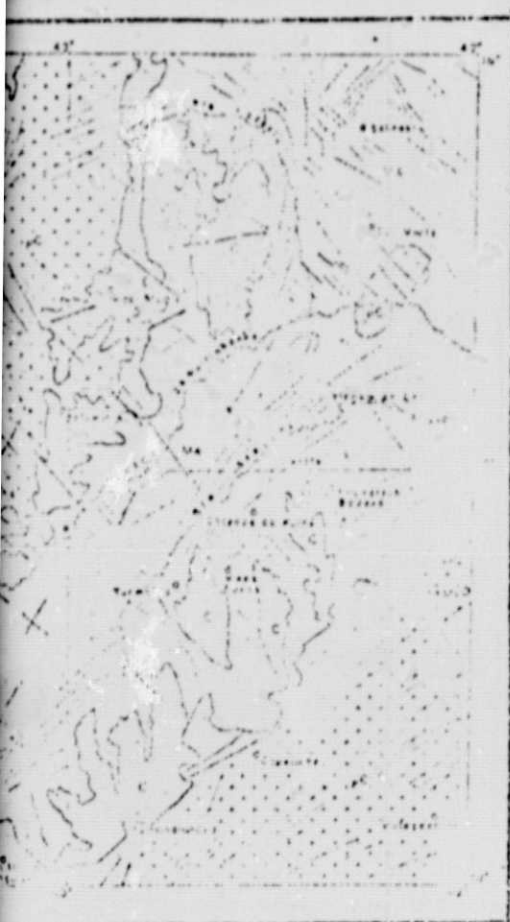
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Fig. 1. A - Tectonic outline of northern Minas Gerais based on I
 B - Area localization. C - Scale: 1:2,000,000. D - Leg
 F - "Brasília" fold belt. G - Precambrian sequences aff

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FOLDOUT FRAME 3

E COBERTURAS 1ª E 2ª PLATAFORMA.

COBERTURAS PANOROMICAS.

- 10 COBERTURAS CARBONIFERAS.
- 11 COBERTURAS MESOZOICAS.

COBERTURAS PRE-CAMBRIANAS.

- 9 COBERTURAS COM PROTOCLASTOS DE GRANITO E GNEISS.
- 8 COBERTURAS COM PROTOCLASTOS DE GRANITO.

F FAIXA DE DOBRAMENTOS "BRASILEIRA".

- 7 Sequências metamórficas.
- 20 Sequências metamórficas afetadas por dobramentos.

SEQUÊNCIAS METAMÓRFICAS E METASOMÁTICAS DE CARÁTER MICROSSINCLINAL.

- 13 Sequências mistas e carboníferas.
- 14 Sequências terrígenas.

SEQUÊNCIAS METAMÓRFICAS DE CARÁTER MESOSSINCLINAL.

- 15 Metamorfismo Anaxo.

G SEQUÊNCIAS PRE-CAMBRIANAS AFETADAS POR DOBRAMENTOS.

- 16 Sequências Metamórficas e Metasomáticas Mesozoicas (Metamorfismo Mesozoico).
- 1 Sequências Metamórficas Epigênicas (Metamorfismo Epigênico).
- 2 Complexos.

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ne of northern Minas Gerais based on LANDSAT images.
ion. C - Scale: 1:2,000,000. D - Legend. E - Platform coverings
d belt. G - Precambrian sequences affected by folds.